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CONTENTS

195 Standardization for Measuring Color

198 Greater Visibility Sought for Warning Lights

200 Collection of Auto Paint Colors Prepared for Forsenic Use

201 NBS Publishes Book on Color Use

202 Program Provides Basis for Color and Appearance Measurements

204 Retroreflectors: Light in the Night

207 Highlights

208 New NBS Chlorine Monitor Aids Pollution Control

210 Video Tape Presentations on Semiconductor Technology Begun by NBS

210 Consumer Measures Adopted at Weights and Measures Conference

211 22 Named in NBS Postdoctoral Competition

212 NBS Test Method Adopted as Tentative Standard by NFPA

213 New Data for Thermocouple Users Issued

214 Getting from Square 1 to Square 2

215 Publications

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Cover: The effects small differences of color have on industry and merchandising is great. In fact, the value of good color control in U.S. industry adds up to millions of dollars annually. To meet the needs of commerce and industry, NBS is working to develop better measurement procedures, more accurate reference instruments and high-quality standards for calibrating instruments for color measurement.

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The National Bureau of Standards serves as a focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. For this purpose, the Bureau is organized as follows:

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The Institute for Materials Research
The Institute for Applied Technology
The Institute for Computer Sciences and Technology
Center for Radiation Research
Center for Building Technology
Center for Consumer Product Safety

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Standardization for Measuring Color

*by William H. Venable**

SEEING and appreciating color in the world is a privilege afforded most of us. Children soon learn to name the colors they see, and later, they develop a feeling for the harmonious combination of colors. There is, however, a vagueness in these experiences with color. If brilliant reds and blues clash, then why are plaid patterns of these colors sometimes pleasing? In going from color to color, when does yellow cease being yellow and become orange, and at what point does orange become red? There are nearly as many opinions on these questions as there are individuals, so that these are clearly problems in psychology or semantics. What role, then, could the National Bureau of Standards have in the field of color? In answering this question, I will first give some background of the "why" and "how" of color measurement.

A Shade of Difference

The thing about color to which individuals are most sensitive, and about which there is the best agreement between individuals, is whether or not two colors are the same. Two people may have difficulty agreeing whether an object is blue-green, emerald or aquamarine. But the same people will usually agree on whether or not two objects side by side appear to be the same color. The human eye is remarkably good at detecting small differences in color. The science of color measurement is

turn page

* Dr. Venable is the leader of the Spectrophotometry Group of the Optical Radiation Section at the National Bureau of Standards.

based on this ability of the eye, but this same ability produces the need in industry to measure and control color precisely.

Generally, in circumstances in which man is supposed to be in control, small differences in color have bad connotations. The effects these small color differences have on industry and merchandizing is great, and proper control of color can have large economic impact. Making the color of a bolt of fabric uniform can greatly reduce the labor required to lay out and cut pieces so that the parts of a single garment will match. Making the labels on a given type of food package the same color from batch to batch keeps a customer from mistakenly associating washed-out appearance with age and allows the grocer to move dated stock in an orderly manner. Producing a finished product to the color specifications of its stylists is necessary if industry is to take advantage of their talents. Failing to achieve a color match in an item assembled from components made by a variety of suppliers may lose sales, even when color is not essential for the use of the product.

Matching and Measuring

To meet the needs of commerce and industry, instruments are needed which can match and measure color. Since the human eye is the final judge in color matching, color measurement must be based on the way the eye works.

Light of each different wavelength produces a sensation of color when it enters the eye, from violet for the shorter wavelengths, through blue, green, yellow, orange and red, as the wavelengths get longer. These are the very "pure" colors which are seen in a rainbow or with the aid of a prism. Only one color can be seen with a single wavelength of light, so that light having only a single wavelength is said to be monochromatic, i.e., single-colored. The colors observed most of the time, however, result from complex mixtures of light from many parts of the spectrum, and any of a large number of different mixtures of light can produce a particular observed color.

From experiments in which observers match given colors with mixtures of monochromatic light, it has been found that the differences in the way people with normal color vision match colors are small. Furthermore, the eye's ability to match colors can be explained in terms of only three different responses to the wavelengths and the amount of radiation entering the eye. It is on these results that the science of color measurement is based.

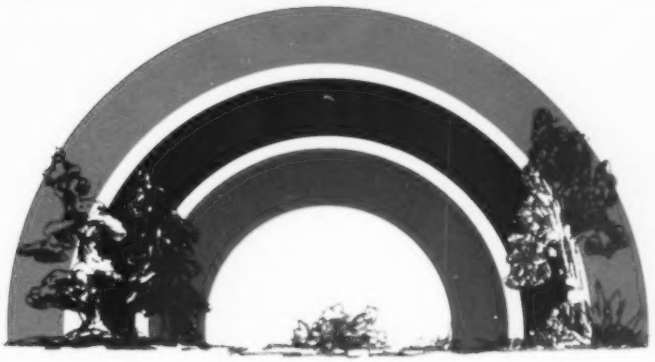
Color measurement has been placed on a formal basis by international agreement on a standard representation of eye response called a "standard observer." The late Dr. Deane B. Judd, who headed the Colorimetry Section of NBS for many years, was a major contributor to this work. Color is really in the eye (and in the mind) of the beholder, but once a standard observer is agreed upon, it becomes reasonable to say that a particular sample of light has a certain color. Three numbers are given to specify the color, one number for each of the three eye responses. Color can be measured by measuring the amount of light present at each wavelength and calculating the three standard observer responses. This is called a spectrophotometric determination of color. Color can also be measured by instruments, called colorimeters, which simulate the three standard observer responses through the use of proper combinations of colored glass filters and photoelectric detectors.

Sources of Color

Most common sources of light produce mixtures of radiation which appear nearly white. When such light strikes an object, part of it is absorbed in the object, and part of it reemerges from the object. If the light emerging from the object appears red when the object is illuminated with "white" light, we say that the object is red. By adopting a standard observer, we can reasonably ascribe a color to light and, by also adopting a standard source of light in addition to a standard observer, we can reasonably ascribe a color to an object. Several standard sources have been agreed upon internationally for representing light from incandescent lamps and conditions of daylight.

Quality Control

If the same color of light emerges from each of two objects under the same illumination, we say that the colors of the objects match under that illumination. Since different sources of illumination contain different mixtures of light of the visible wavelengths, the only way to be sure that the color of two objects will be the same with all sources of light is to make the two objects match under monochromatic light at each wavelength. If this condition can be achieved, the light emerging



from the two objects will be the same for any mixture of light of different wavelengths. The object of quality control of color in industry is usually to match colors in this way. At various points in the manufacturing process, the product can be examined by instruments called spectrophotometers to determine what the object does with light at certain key wavelengths which depend upon the composition of the material. If a departure from what is expected is noticed, the manufacturing process is corrected.

When different materials are involved, an exact wavelength by wavelength match of color is not possible. For example, when plastic and painted metal are used side by side in a given object, the same coloring agents often can not be used for both materials. In this case the color measurement is used as an aid in obtaining compromise colors which match, or at least do not clash, under the types of illumination with which the object will probably be seen.

Roles of the Standardizing Laboratory

There are two strongly interactive aspects of standardization in color measurement. The first is to choose a standard observer which best represents the average judgment of a large number of skillful observers. The present standard observer fails to do this under certain conditions. This problem is being worked on in a number of laboratories throughout the world, but at present NBS has no structured effort on this part of the problem.

Once the standard observer has been agreed upon, instrument performance must be standardized. In long-term production, it is important that quality control instruments do not change from day to day, and that the instruments within a given operation agree with one another. In commerce, the specification of color requires that colorimetric measurements accurately represent the standard observer.

The NBS effort in this second aspect of color standardization is one of the responsibilities of the spectrophotometry group of the Optical Radiation Section. Through basic measurement research, by assisting manufacturers of colorimetric instruments to improve their products, by helping to develop better measurement procedures and by providing high quality standards for calibrating instruments for color measurement, this group is promoting more practical and more accurate color measurement.

Advances Predicted

An exciting new era in colorimetry is beginning. Space-age electronics and laser-inspired optics have combined to make possible instruments with sensitivity and precision which were only dreams a decade ago—instruments which at last can be far more sensitive and discriminatory than the human eye. The same technological advances have also made possible rapid processing of colorimetric data, computer decision making and sophisticated control mechanisms with which to perform automatic color quality control in manufacture. Taking advantage of these advances requires an improved level of accuracy in standardization which presents a strong challenge to the standards laboratories of the world.

NBS Responds

Responding to the challenge from colorimetry and a number of other fields, from chemical analysis to solar heating, in which the measurement of electromagnetic radiation is important, NBS, in the spring of 1973, launched a comprehensive revised program in spectrophotometry in the Institute for Basic Standards.

The backbone of this program is a new generation of highly accurate reference instruments for measuring the way light of each wavelength interacts with objects. A reference instrument to measure the fraction of incident light that passes through a transparent object such as a piece of colored glass is already in operation. The final touches are being applied to a reference instrument to measure the fraction of light reflected from smooth surfaces. A reference instrument for measuring retroreflectors, such as are used to make vehicles and road signs visible to motorists at night, is partially completed. Construction has begun on a reference instrument to measure the fraction of light transmitted diffusely, as through ground glass or translucent plastic, and reflected diffusely, as by the paper on which this article appears. This is soon to be followed by an instrument to make accurate angle-by-angle study of such diffuse reflections and transmission possible. Finally, reference instrumentation is planned that will be used to measure fluorescent colors such as those used in safety vests for policemen and

continued on page 214

Greater Visibility Sought for Warning Lights

IT IS 8:30 on a wet, damp fall evening. The baby is running a fever and you're on your way to the drug store to pick up a prescription.

The rain has slicked the roads and the driving is hazardous. No convenient drugstore is open so you're forced to go to the all-night chain store in town. To get there you have to travel a congested commercial route. Your grip tightens on the steering wheel.

Tonight the glare of oncoming cars is almost blinding. Their beams reflect off the wet pavement and create a swirl of color. It is made even worse by the lighted signs of stores along the route. All of the colors seem to merge and collect on the raindrops splattering the windshield.

Up ahead there is a flashing red light. Set against the background, however, it is hard to tell whether its part of a roadside sign or a warning signal.

You strain to see, wiping moisture off the inside of the windshield. Too late you realize the flashing light is from a police car blocking traffic because of an accident. A line of traffic has backed up.

You apply the brakes instinctively—and hard. The car swirls on the slick roadway . . . and fishtails into the car stopped in front. It, in turn, rams the car ahead of it. What began as a minor fender-bender has suddenly swelled into a major accident. You're shaken—but unharmed. The rear end of the car, however, is mangled. The car will have to be towed.

FROM early childhood we are taught that certain colors have special meanings. Green is a safe color, it means we can proceed. Yellow is a cautious color, it tells us to slow down and be alert. Red is a warning color, it tells us to stop what we're doing or to take particular notice of what is happening.

Scientists and engineers at the National Bureau of Standards have been studying colors we see everyday that deliver special messages about our environment. Specifically, they have been studying warning signals associated with emergency vehicles, particularly police cars. NBS has been performing the work for the National Institute of Law Enforcement and Criminal Justice, part of the Department of Justice's Law Enforcement Assistance Administration.

They have found many of the same things experienced by our friend above—only in a more scientific and less empirical fashion. Today's driver is beset by a myriad of warning signs and signals. These often are set against congested backgrounds that swallow up the signs and signals, leaving the motorist totally confused.

Just as confusing is the lack of uniform policy among the numerous public and private agencies which display warning signals on their vehicles. For the driver today there is a bewildering array of warning lights. A private security agency may use amber lights on its marked vehicles, snowplows and highway maintenance trucks may display blue lights, tow trucks may use red or white lights—and emergency vehicles such as police cars, fire trucks and ambulances may all shine red lights . . .

or they may use a combination of red with other lights.

Since the 1920's the National Committee on Uniform Traffic Laws, a private, voluntary agency located in Washington, D.C., has been attempting to promote unity in vehicle warning systems. There has been little agreement, however, on what constitutes the most effective warning lights. It is at this point that NBS has come into the picture.

To be effective, a warning light has to be both seen and recognized. It would do little good to develop a warning system visible from a great distance or in congested city streets unless the driver viewing the light understood the message being conveyed and took appropriate action.

Lights have become particularly important as early warning devices since many of our cars are now engineered to keep out external noises (including sirens) and have numerous options (such as air conditioners and stereo tape players) that boost internal noise levels.

Guidelines set forth by NBS for emergency lights specify that they should be: readily noticeable under all conditions, clearly understandable, compatible with the environment, easy to use, reliable and of low cost—both in dollars and energy demand.

In its studies, NBS found white light to be the most visible and recommended it as an "essential" part of a warning system for police vehicles.

"White is the most visible because there is no filtration and because it produces the greatest intensity for a given energy input," notes Avery T. Horton, program manager for emergency equipment in NBS' Law Enforcement Standards Laboratory (LESL). "When you introduce a color filter you reduce the intensity. The only means of converting white light into color light is to take away some of the white light," he adds.

But because a pure white emergency signal might get swallowed up in other white lights such as headlamps and street lights, NBS recommends alternating white with red to connote a police emergency. Red light was picked because it already signals danger or emergency in most peoples' minds, it is more visible through haze than most other colors and it can be identified more readily by persons with vision problems.

Blue light was the next choice of NBS experts. Blue was recommended to signal the non-emergency "presence" of a police vehicle.

Thus NBS recommends that all police vehicles be equipped with a white flashing light and, wherever possible, with red and blue lights. The white light would be used at all appropriate times to attract attention. The red light would be flashed with the white in an emergency, such as an accident, and the blue would be used with white in a non-emergency situation, such as assisting a motorist with engine trouble.

NBS also believes that color plays an important part in recognition of the police vehicle itself. "We believe the vehicle should be painted to be conspicuous," Horton says. The most conspicuous is a harlequin design in which major surfaces of the car (sides, rear, hood, roof) are divided into two to four rectangles painted alternately with light and dark colors. "In other words, an extremely coarse checkerboard," an NBS report notes.

The guidelines were developed for LESL by Arthur I. Rubin, Gerald L. Howett, Kenneth L. Kelly and E. Thomas Pierce of the Sensory Environment Section of NBS' Center for Building Technology. □

Collection of Auto Paint Colors Prepared for Forensic Use

*by Charles G. Leete**

AUTOMOTIVE paint is such a commonplace substance that the motoring public is often unaware that small chips can be very valuable clues in hit-and-run investigations.

Paint transfer occurs in many collisions involving vehicles. At the scene of a hit-and-run incident, for example, police personnel frequently collect paint samples from a struck vehicle, from related debris, or from the clothing of a struck pedestrian, either in smear form or as actual chips.

Criminalists are then asked to examine the paint samples and to classify or individualize them. A classification helps to determine the probable make, model and year of the vehicle involved and is useful in the early stages of an investigation. An individualization serves to establish that the paint came from a particular vehicle and is a more specific characterization. The simplest methods of paint characterization involve the microscopic examination of color, surface texture, surface markings and layer structure and the matching of broken edges.

The Law Enforcement Standards Laboratory (LESL) at the National Bureau of Standards, as part of its effort to develop performance standards and reference materials for the National Institute of Law Enforcement and Criminal Justice, Department of Justice, is establishing an auto paint reference collection and data supplement for use by State and local forensic science laboratories.

In 1973, LESL conducted a study of the availability of standard reference collections and their relative importance to forensic laboratories. The study showed that an automotive paint reference collection was of prime importance. LESL, with the cooperation of the auto manufacturers and their paint suppliers, is filling this need.

* Mr. Leete is a Research Associate in the Laboratory Performance Section of the Institute of Applied Technology at the National Bureau of Standards.

The new auto paint reference collection developed at NBS is designed to aid forensic science laboratories in identifying paint samples collected at the scene of hit-and-run incidents.

Reference Collection

This first reference collection consists of samples of approximately 140 paint colors used on 1974 model domestic passenger vehicles. All the color samples in the Collection were prepared from actual production paint patches. The original-finish paint suppliers applied the paint to primed panels. Samples approximately 25 x 40 millimeters (1 x 1½ inches) in size were then cut, and each sample was placed in a hinged plastic slide holder. The holders, in turn were placed in special plastic slide containers which were assembled in three-ring binders. The samples can be removed from the hinged holders as needed, for ease in visual or microscopic examination.

The samples are arranged in the Collection according to their color classification (white, gray, black, pink, red, brown, orange, yellow, olive, green, blue, violet and purple). However, the flexibility of the system permits the user to organize the samples in any way he wishes.

Data Supplement

The technical data supplement to the Collection is divided into two sections. In the first section, the samples are listed in the order of the reference number assigned to each sample. In the second section, they are listed according to their color classification, in the same order as in the Reference Collection. In both sections, the following information is given for each sample:

- The type of paint: metallic or non-metallic.
- The vintage of the paint: introduced in the current model-year or a carry-over (c/o) from prior years.
- The name of the automotive manufacturer using the color and his reference number for the color.
- The 1974 models on which the color was used.

LESL and the National Institute of Law Enforcement and Criminal Justice have arranged for the distribution of the reference sets to qualified forensic laboratories throughout the Nation. □

NBS to Publish Book on Color Use

THE National Bureau of Standards will publish a booklet designed to foster a greater understanding of color relationships, with specific applications in home decorating, cosmetics use and selection of wearing apparel. The booklet, entitled *Color in Our Daily Lives,* is to be published as part of the NBS Consumer Information Series.

Color in Our Daily Lives discusses basic concepts, such as families of colors and the meaning of lightness, darkness, grayness and vividness. In addition, it explains how to use the relationships among the hues. Color effects, such as induction and harmony, are also discussed with suggestions for their applications. The text is simple and in non-technical format. The booklet is profusely illustrated in full color, in keeping with the author's belief that color relationships must be sensed, or felt, and that if presented properly color can, in effect, "tell its own story."

The author, Dr. Deane B. Judd, now deceased, was one of the world's foremost scientists in the field of colorimetry and color vision. He pursued an outstanding career at the National Bureau of Standards spanning over 40 years. He served as president of the Optical Society of America (1953-55), president of the Inter-Society Color Council (1940-44), and was the recipient of numerous awards for service and professional excellence. Judd also authored a book and many technical papers in his field. Publication of *Color in Our Daily Lives* represents a posthumous fulfillment of his long-held desire to help enrich the lives of laymen and consumers by promoting greater understanding of the practical applications of color principles.

Carl E. Foss, retired senior officer of the Munsell Color Company and Judd's colleague of many years, served as consultant in completion of the manuscript and was responsible for assuring the fidelity of the color illustrations. □

Program Provides Basis for Color and

*by Theodore W. Lashof**

IN August 1972, the National Bureau of Standards established a color and appearance collaborative program to provide a participating laboratory with a means to check periodically the level and uniformity of its testing in comparison with that of other laboratories. An important by-product of the program is that it provides a realistic picture of the state of the art in appearance measurements for NBS and voluntary standardization activities.

The interchange of components and products that must match in color and appearance is of interest to producers of such products as paint, plastics, paper, textiles, food and cosmetics, as well as to the users of these products, which include the automotive and appliance industries, highway departments, government and the consumer. Failure to adequately control the appearance and color of consumer products is a major cause of consumer dissatisfaction.

* Dr. Lashof is chief of the Laboratory Performance Section at the National Bureau of Standards.

Growing Participation

Today there are nearly 100 participants in the program, which is sponsored by the Manufacturers Council on Color and Appearance—a nonprofit organization of manufacturers of color and appearance instrumentation. Although this part of the instrumentation industry is small—about $15 million annually—the instruments control billions of dollars worth of product.

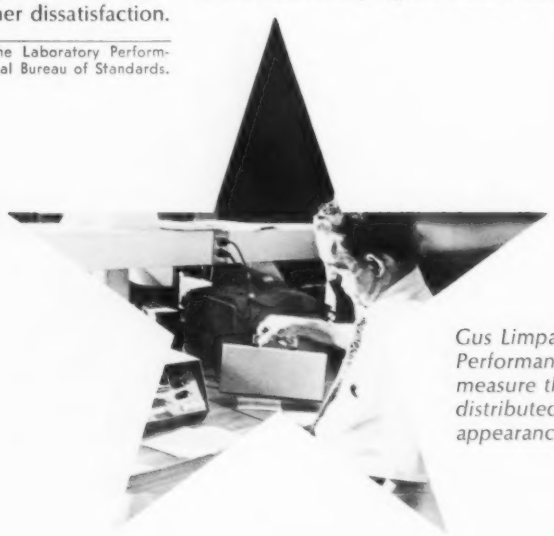
Program participants have found that they are deriving some direct economic benefits from the program. Both manufacturers and customers have reported fewer disputes from errors in testing as well as an improvement in the uniformity of the product. Instead of scheduling costly recalibrations of instruments at regular intervals, some participants are allowing the results of the collaborative reference program to show them when an instrument needs calibration or overhaul. In addition, the collaborative reference program checks both the instrument and the operator under actual testing conditions, while calibration procedures test only the instrument. In fact, undiscovered errors in or incompleteness of calibration procedures have been discovered through the collaborative reference program.

Test Methods and Procedures

The program was initiated with two test methods: 60° gloss, and color and color difference. It was extended in 1973 to include 20° and 85° gloss and color materials research, and, most recently, reflectivity of retroreflective materials. This latest addition will center on highway sign materials, at least during the first year, but may be extended to retroreflective road paints at a later time.

Under this program, participants select the tests in which they wish to participate. This choice is made on joining the program, but additional tests may be added at any time. Also, new participants may enter the program at any time.

Test samples are distributed quarterly to participating laboratories for analysis. For the gloss and color and color difference methods, the samples are normally opaque-colored paint chips. The samples for each gloss method consist of two levels of four specimens each. Two pairs of



Gus Limparis of the NBS Laboratory Performance Section prepares to measure the gloss of a test sample distributed under the color and appearance collaborative program.

Appearance Measurements

test specimens comprise the samples for color and color difference. There is a small color difference between the specimens of a pair and a big difference between the pairs, the colors of which are selected from the entire color spectrum. Each quarter, the samples for reflectivity are at two levels, with two specimens of highway sign sheeting for each level.

In every case, the sample is taken from a uniform production run. The specimens are then cut from the sample and randomized before being assigned to individual participants. Provisional results are provided with the specimens for one or both of the test levels, depending on the method. These values permit the participants to detect serious discrepancies without delay.

Each participant tests the samples, following instruction provided for each test method. The full check on a single instrument normally takes no more than 30 minutes. The participant then sends the test results, together with other relevant information such as test conditions, the make and model of the instruments used and so forth, to NBS for analysis.

Analysis of Results

At NBS, industry means, best values and other statistics are developed from the data. The best values are estimates based on careful examination of all data, both current and past, with special attention to results obtained by NBS and other recognized reference laboratories in this and other countries.

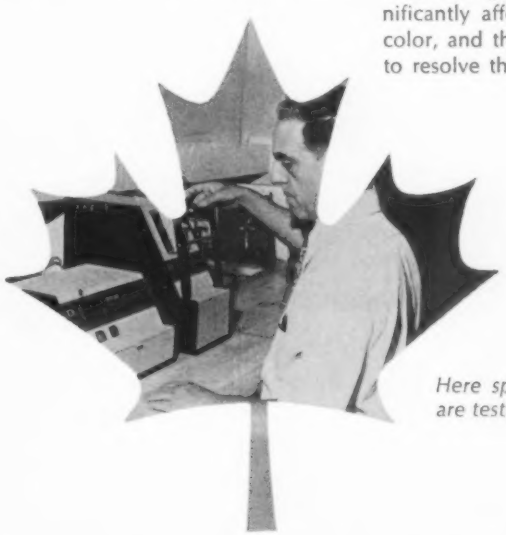
A computer-prepared individualized report ("quick" report) is sent to each participating laboratory reporting data on time. This report shows the industry mean values and the deviations of the laboratory's results from these values for each method.

A longer summary report showing the data from all participants is also prepared. In this report, each laboratory is identified by a code number, so that the information is maintained on a confidential basis. However, instruments are identified by type, enabling participants to compare their results with those obtained on similar instruments. This report includes test averages, best values and standard deviations for individual participants and for the group as a whole.

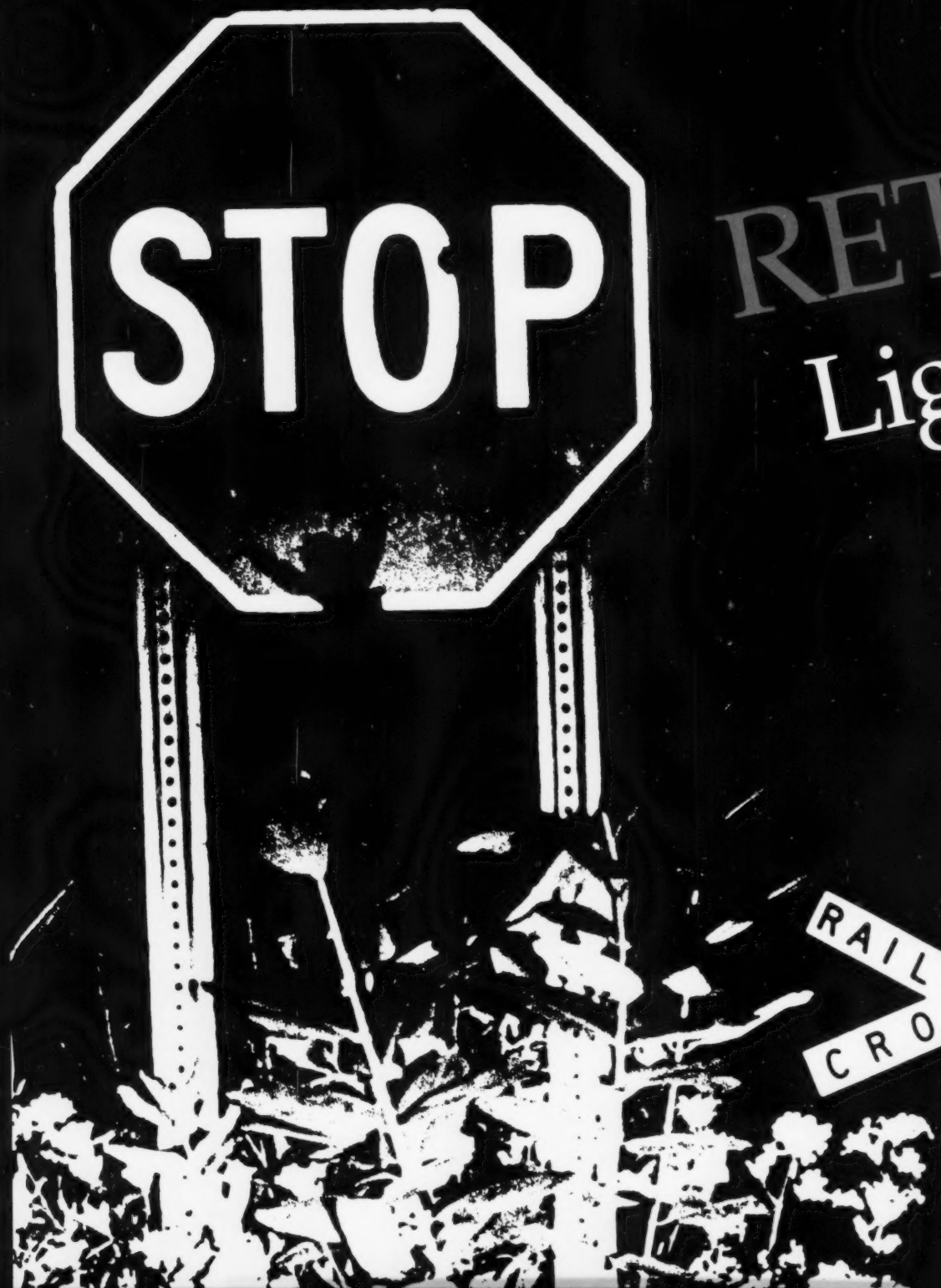
Exchange of Ideas

Annual conferences are held for participants, instrument manufacturers and representatives of government agencies to discuss what the collaborative reference program is accomplishing and to exchange ideas and suggestions for additions or modifications. The conferences provide attendees with a forum for obtaining state-of-the-art information on instrument performance, calibration of physical standards and testing procedures. In the past, representatives of NBS, the Canadian National Research Council and industry have made short presentations on such subjects as problems of measurement of gloss, development of a new gloss standard, metameric samples as a testing tool and the new CIE color difference equations.

One of the most important achievements of the program to date is that it has brought together two of the major basic standards laboratories of the world—the U. S. National Bureau of Standards and the Canadian National Research Council—in focusing attention on problems of applied optics. These two laboratories now repeatedly agree well within one gloss unit, and their pooled value for 60° gloss serves as the reference value for the collaborative reference program. They have confirmed that the differences among various procedures for determining absolute reflectance significantly affect the measurement of color, and they are now cooperating to resolve these differences. □



Here specimens are tested for opacity.



RETRO

Light

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RETROREFLECTORS: ... in the ...Night

WHAT do cats' eyes and highway signs have in common? They both act as retroreflectors.

Almost everyone has noticed the eerie, sometimes even frightening appearance of animals at night, as their eyes seem to glow in reflected light. One may speculate that just as reflective highway signs alert the motorist to many road hazards, so early man was often warned of danger by light from his campfire reflected in the eyes of lurking predators. In both cases, the light is said to be retro-reflected, giving it a particularly bright appearance.

The principles of retroreflection have been understood for centuries. However, it is only within the last 50 or 60 years, with the wide use of the automobile, that this area of optics has received important commercial application. Today, the uses of retroreflective materials are many. They are purchased in very large quantities by government agencies for use on highways, including the interstate highway system. They are applied to bicycles and motor vehicles to make them more visible at night. And they assist pilots by improving the visibility of runway markers.

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Although most uses for retroreflective materials are safety-related, some are not. For example, these materials play a key role in helping railroads locate and make maximum use of their rolling stock. Color-coded retroreflective numerals, strips or dots applied to the side of railway cars identify the cars by their individual inventory control numbers and by the particular type of car. Optical scanners, set at certain points along the track, "read" and record this information as the train passes by, thus making it possible for railroad management to locate an individual car or to determine the distribution of boxcars throughout the rail network.

Performance Requirements

Large sums are spent for retroreflective materials, but purchasers have often found it difficult to specify performance for the materials they buy. Performance is of concern, not only from the standpoint of the brightness of reflected light, but also from the standpoint of its color. It is important, for example, that the yellow hues used in warning signals be of consistent color quality on all road signs so the driver can rely on color as well as shape and symbol to discern the signs' meanings. Seven colors—silver, blue, yellow, red, green, brown and orange—are currently used for marking the interstate highway system.

Since 1971 the National Bureau of Standards, under contract to the Department of Transportation, has been working to develop instrumental test methods that could be used to evaluate the performance of retroreflective materials and to aid in the preparation of specifications for their purchase. Isadore Nimeroff, NBS physicist, points out that many factors must be considered in developing or selecting test methods to be used for retroreflective materials. "For example," Nimeroff said, "nighttime color of roadsigns varies slightly with the angle of light coming from auto headlights and with the observation angle from the driver's viewpoint. Therefore, color measured from one vantage point, or geometry, may not be adequate."

The particular application for the retroreflective material is also of concern. "Materials used for raised road delineator markers should perform well for light entering from less than a 45° angle, as from an auto headlight," Nimeroff noted, "whereas retroreflective paint used for marking highways and airfield runways must perform with light entering at a 75° to 88° angle."

Retroreflectors

Retroreflected light is light that is returned or reflected along a conical path parallel to the beam produced by the original light source. Retroreflectors are of two general types: Cube corner retroreflectors that display three mutually perpendicular surfaces upon which incoming light is successively reflected and then returned to its source; and spherical lens retroreflectors, in which incoming light rays passing through a lens are focused on a reflecting surface. The reflected light then passes out through the same lens which redirects it toward the original light source.

NBS investigations have resulted in a number of recommendations for instrumentation and measurement techniques to be applied to retroreflective materials. Studies have been undertaken for daylight and for nighttime viewing conditions. Many of the NBS recommendations are now being utilized for purchase of retroreflective materials used in the interstate highway system. These recommendations are also available for use by State highway officials. Information on methods for testing retroreflective materials is available from the Office of Traffic Operations, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. 20590.

"The need for adequate test methods in this area is especially important at this time," says Nimeroff. "This is so in part because large investments are now being made in new highway signs that will display both international symbols and distances in metric." □

HIGHLIGHTS

Noise Control Conference

NBS is cooperating with the Institute of Noise Control Engineering in presenting the 1974 International Conference on Noise Control Engineering, known as INTER-NOISE 74, to be held September 30 to October 2, 1974, at the Shoreham-Americana Hotel in Washington, D.C.

The sessions will cover recent government activities in noise control and offer perspectives from industry and labor as well as experts from other countries. Latest developments in the Federal regulatory arena will also be highlighted. Information is available from INTER-NOISE 74, ARL-PSU, P.O. Box 30, State College, Pa. 16801.

Portable Pollution Detector

NBS has delivered a portable air pollution monitoring laser instrument to the Environmental Protection Agency. Designed and built by NBS scientists, the instrument almost instantaneously measures the size distribution and total number of particles in air in the size range 0.2 μm to 4 μm—the range most often involved in lung interaction. In addition to its potential for air pollution studies, the device may find application in general aerosol studies, in smoke detector investigations and in studies of the physiological effects of particulates.

Measurement Seminar

A Time and Frequency Seminar to be held at the Bureau's Boulder, Colo., laboratories on October 1-3, 1974, will present a general overview of the state of the art of precise measurement of time and frequency. Topics will include: Definitions and the different time scales in common use; measurement of frequency and frequency stability; clock performance and simulation; and future trends in the measurement, use and distribution of time and frequency.

For information, contact Byron E. Blair, NBS, Boulder, Colo. 80302. Telephone: 303/499-1000 ext. 3542.

Accuracy in Trace Analysis

The 7th Materials Research Symposium to be held October 7-11, 1974, at NBS' Gaithersburg, Md., campus will explore the various factors that contribute to obtaining accurate analytical results of trace constituents. Particular emphasis will be placed on the whole analysis, from the time the sample is taken through the interpretation of results, rather than upon the measurement only. Measurements of trace chemicals in rocks and minerals, air, water, biological fluids, plant and animal tissues and high-purity materials will be discussed.

For information, contact Ronald B. Johnson, B348 Materials Building, NBS, Gaithersburg, Md. 20234. Telephone: 301/921-2835.

New Industrial SRM's

Two new Standard Reference Materials (SRM's) were issued recently by NBS—SRM 276, Tungsten Carbide, and SRM 478, Cartridge Brass Microprobe. The tungsten carbide SRM was prepared to meet industry needs arising from the rapid growth of carbide technology with a consequent demand for more stringent specifications on physical and chemical properties. The cartridge brass microprobe SRM is the latest in a series of SRM's (479 to 483) designed to provide standards suitable for quantitative microanalytical methods such as electron probe microanalysis.

For additional information, write or call the Office of Standard Reference Materials, NBS, Washington, D.C. 20234. Telephone: 301/921-2045.

Platinum Standard Changed

As of September 1, 1974, the results of thermometric tests of thermocouple materials that are performed in accordance with items 221.112 a, f, g and h of NBS Special Publication 250 have been reported against the new platinum thermoelectric reference standard, designated Pt-67. This new standard replaces the previous thermoelectric reference standard known as Pt-27. The properties of Pt-67 and the differences between it and the previous standard are discussed in NBS Monograph 125, which is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, as SD Catalog No. C13.44:125 for $4.55.

Congressional Visit

Congressman Edward I. Koch (N.Y.) and John B. Conlan (Ariz.) visited NBS recently to obtain a firsthand view of computer capabilities and problems related to data confidentiality and security. Through discussions with members of the Bureau's Institute for Computer Sciences and Technology, they sought to get a better understanding of the technical implications of numerous bills which Congress is considering to safeguard individual privacy. These bills would prescribe rules for the collection, processing and dissemination of personal information. □

New NBS Chlorine Monitor Aids Pollution Control

ON May 23, 1973, an unexplained massive fish kill in the picturesque James River in Virginia alarmed scientists, state officials and fishermen alike. Excess chlorine in the effluent from a sewage treatment plant emptying into the river was the prime suspect for the kill. But it took researchers a week to confirm the cause of the poisoning because they lacked a sensitive method for detecting chlorine in the river. By the time the excess chlorine levels could be reduced, an estimated five to ten million fish had died.

Several weeks after the kill, scientists from the Virginia Institute of Marine Science (VIMS) in Gloucester Point asked scientists at the National Bureau of Standards (NBS) to tackle the problem of developing a monitor for the low levels of chlorine that are found in waste water effluents and natural waters. After nearly a year of effort, Dr. George Marinenko, with the assistance of other NBS scientists in the Analytical Chemistry Division, has developed a portable, sensitive chlorine monitor which can detect trace levels of chlorine—down to the parts per billion range. That is so little chlorine that it is missed by most other methods, but it is sometimes enough to kill trout and other fish or dangerously disturb their breeding process.

Robert Huggett (left) of VIMS and Dr. George Marinenko of NBS field test monitor on board research vessel on James River, Virginia.

Called an electrochemical flux monitor, the device was developed in cooperation with VIMS personnel under the auspices of the NBS Measures for Air Quality program, headed by Dr. James McNesby.

"Methods are readily available for detecting chlorine in fresh water," says Robert Huggett, who heads ecology-pollution research at VIMS, "but none are effective for shipboard use in the estuarine environment where the water composition is complicated by salt and other dissolved compounds." In addition, none of the standard fresh water methods is accurate in the parts per billion range. Another serious problem with standard chlorine detection devices is that many are not portable. Taking water samples on-site and delivering them back to a laboratory facility, which may be many miles away, can alter the sample and lead to errors in the analysis.

Overcome Drawbacks

The electrochemical flux monitor overcomes most of the drawbacks of standard methods, according to Marinenko. In addition to its sensitivity, the most important feature of the new monior is its portability. An early prototype instrument has now been redesigned into a small, light package—about the size of a breadbox—for use aboard small outboard runabouts as well as larger research vessels and shore-based laboratories. The electronic portion of the monitor was designed and built by Ronald Shideler of the NBS Analytical Chemistry Division.

Another significant feature of the monitor is that it measures total chlorine. Marinenko explains that chlorine is used in sewage treatment effluent to kill bacteria and to oxidize organic matter before release to the receiving streams. Hypochlorites result from the reaction of chlorine and water and chloramines result from the reaction of chlorine and ammonia, a common constituent of wastewater. Marinenko's system detects hypochlorites and chloramines as well as chlorine.

In particular, notes Marinenko, chloramines, which go undetected by other methods, are thought by some researchers to be even more toxic than chlorine itself.

Residual chlorine in these forms is highly toxic to fresh water and marine organisms. The National Water Quality Laboratory of the Environmental Protection Agency, for instance, recommends that trout streams contain no more than two parts per billion residual chlorine.

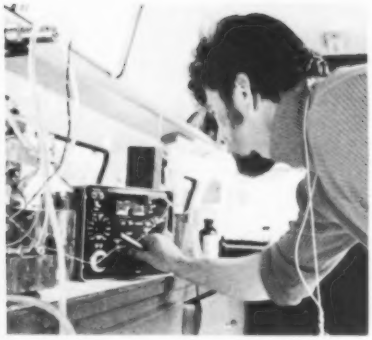
During a 1974 fish kill on the James River, Marinenko and Huggett aboard a VIMS research vessel de-

tected 25 parts per billion of chlorine with the monitor. This time, there was no delay. The waste water treatment facility was notified immediately to cut chlorine levels, the chlorine levels in the river dropped and the fish stopped dying.

In another recent test, Marinenko and Dr. John Taylor, chief of the NBS Air and Water Pollution Analysis sections, accompanied officials from the Water Resources Administration of Maryland on a day-long examination of a stream and its tributaries in a rural community in Maryland. The monitor was easily loaded in the back of a van and survived without mishap the bumpy ride along steep dirt and gravel roads bordering the streams.

At most points on the trip, Marinenko found that chlorine levels were below the detection level of the device. However, at the direct outlet from a small wastewater treatment plant, the monitor detected 5.5 parts per million of chlorine. A little downstream from the effluent outfall, it measured 0.5 parts per million. A chemist from the Water Resources Administration was unable to detect the lower concentrations of chlorine with a different method, but at the higher levels his method agreed with the results from the chlorine flux monitor. On samples containing known amounts of chlorine, both methods were also in agreement.

Marinenko is still working to improve the sensitivity of the system. In the meantime, he sees a variety of uses for the device. In addition to on-site monitoring of chlorine in marine environments, the device could be used to monitor chlorine levels in swimming pools and water and sewage treatment plants. The sensitivity of the instrument may also make it valuable to researchers who would like to study the effects of very low chlorine levels on aquatic life. Most of these studies have not been performed because there has been no accurate way to measure very low chlorine concentrations. □



Collecting water samples for testing from stream in rural Maryland.

Monitor loads easily into shore-based laboratories such as this van used in testing streams in rural Maryland for chlorine content.

Measurement Principles

The electrochemical chlorine flux monitor itself is based on the well known principle that chlorine, chloramines and hypochlorites will oxidize iodide to iodine at the proper pH. If one can monitor the concentration of iodine, one has a way of monitoring the concentration of chlorine. An electrochemical system has been used to monitor iodine concentration. It consists of a platinum microelectrode and a saturated calomel electrode (SCE) with a microammeter connected across the cell. In the presence of iodine, the platinum microelectrode functions as a cathode and the SCE acts as an anode. The electrical current resulting from the electrochemical reaction is recorded as the monitored signal.

For calibration purposes, an accurately known amount of iodine may be generated coulometrically which is a novel and unique feature of the NBS instrument. Consequently, the amount of electrochemically generated iodine needed to produce an amperometric signal identical to the signal obtained from unknown water corresponds to the unknown chlorine concentration.

The NBS monitor was constructed on these principles, according to Marinenko, and is made of two cells—a calibrating iodine generator and an iodine detector. He points out that an important part of the device is a synchronous liquid pump that allows the sample to be monitored at a constant flow rate.

Video Tape Presentations on Semiconductor Technology Begun by NBS

COLOR video tape casette presentations on improvements in semiconductor measurement technology are being developed at the National Bureau of Standards for the purpose of more effectively disseminating the results of work done at NBS to the semiconductor industry.

The first video tape, titled "Defects in PN Junctions and MOS Capacitors Observed Using Thermally Stimulated Current and Capacitance Measurements," is available for distribution on loan without charge. It is presented by Dr. Martin G. Buehler of NBS and runs 35 minutes. As an added feature, Dr. Buehler can be available for a telephone conference call to answer questions and provide more detailed information, following a prearranged showing of the video tape.

In this video tape presentation, Dr. Buehler describes methods he has developed to detect and characterize defects which can control such device characteristics as lifetime and junction leakage. These methods show great promise as diagnostic tools in the fabrication of bipolar and MOS devices. The methods are straightforward and the data reduction is reasonably simple. The number of different kinds of defects and their densities may be obtained with little effort and simple apparatus. Positive identification of these defects may be obtained with more effort and more sophisticated apparatus. Of more importance, the measurements characterize defects in an environment which is identical to that of the finished product. Thus, the answers derived are directly applicable to process control and device design. Their use can contribute to greater yield in the manufacturer's plant and to greater uniformity and reliability in the user's.

These methods involve thermally stimulated capacitance and current measurements which utilize the ability of defects in the vicinity of a p-n junction or in an MOS capacitor to trap holes or electrons and emit them after receiving sufficient thermal energy. Values for defect densities, energy levels and emission rates can be derived from these measurements, where the limit of detectability can be as low as 10^{10} defects/cm^3. These values provide sufficient information to positively identify the defects.

Persons wishing to borrow the video tape of Dr. Buehler's presentation should contact Harry A. Schafft, National Bureau of Standards, Washington, D.C. 20234. Additional video presentations will be announced as they become available. □

Consumer Measures Adopted at Weights and Measures Conference

AT their national meeting held recently in Washington, D.C., delegates to the 59th annual National Conference on Weights and Measures (NCWM) approved measures that define dimensional tolerances for glassware and paper products. For example, working with the American Glassware Association, the Conference set a 7.4-milliliter (¼-ounce) tolerance for blown tumblers and stemware with capacities of 150 ml (5 oz.) or less. Glasses with greater capacities must be produced with a 5-percent tolerance. Similar tolerances were set for bowls, blenders, pitchers, dessert and soup bowls, casseroles, loaf pans and roasters.

In cooperation with the American Paper Institute, the Conference defined the allowable difference between actual and declared dimensions for paper towels, paper napkins and facial tissues as plus or minus .32 centimeter (⅛ inch). For toilet tissue, it was set at plus or minus .16 centimeter (1/16 inch).

The National Conference on Weights and Measures comprises weights and measures enforcement officials on the State, county and

municipal levels. The annual meeting brings together these officials along with representatives of business, industry, trade associations and consumer groups to discuss matters of common interest. Dr. Richard W. Roberts, director of the National Bureau of Standards, serves as president of the NCWM, while Harold F. Wollin, chief of NBS' Office of Weights and Measures, is the Conference executive secretary.

The Nation's drift toward the metric system and implications for weights and measures authorities were major topics at the recent meeting. John H. Lewis, outgoing Conference chairman, urged a calm approach toward changeover from the customary to the metric system. The Conference's Metric Planning Committee, in a report adopted by the Conference, stated: "The Conference should strive to move forward at every opportunity in all possible activities, rather than merely help coordinate in those areas where movement is already taking place."

In addition, the committee adopted the following metric symbols for use in package labeling: meter—m, millimeter—mm, square meter m^2, liter—l, gram—g and kilogram—kg.

In keeping with the international implications of metric conversion, the role of the NCWM was more clearly defined with respect to the International Organization of Legal Metrology (OIML). A resolution was adopted defining the limits of moral obligation that the NCWM is willing to accept with regard to recommendations on which the NCWM agrees that the United States should cast an affirmative vote and on which the United States has cast that vote.

The first census ever undertaken of the weights and measures system in this country was also accepted by the Conference. A summary of the census was distributed to delegates by the Committee on Education, Administration and Consumer Affairs. The primary object of the survey is to document the personnel and physical resources in the field of weights and measures in order to promote more effective planning.

The first portion of the census contains the numbers of people, their duties, titles, status of employment and average salaries. The second phase, expected to be delivered at an interim committee meeting in January, will summarize physical space allocations, equipment resources, types of programs and laws and regulations of weights and measures offices around the country.

In other actions, the timing device code in Handbook 44 was finalized. The devices, which meter by increments of time such services as automatic car washes, parking or laundromats, are now covered. States may now formally initiate action against offenders.

The delegates defeated a proposal that would have adopted a three-quart milk container as a standard package size. They also tabled for 1 year action on a proposal to insure uniformity in unit pricing, urged completion of ongoing studies before deciding to endorse the sale of eggs by weights instead of by count and tabled indefinitely a proposal to develop a model state menu regulation for "fast food" restaurants, delicatessens and supermarkets.

Finally, the Conference decided not to add voluntary or permissive temperature compensation of gasoline sold at retail to Handbook 44. The Conference anticipates, however, that temperature compensation would become mandatory when the technology of a temperature compensator for retail use is developed. □

22 Named in Postdoctoral Competition

THE National Bureau of Standards has announced winners of the 20th annual competition for postdoctoral research associateships. Twenty-two scientists who recently received doctorates in the physical sciences and engineering will spend a year at NBS undertaking advanced research projects guided by senior NBS scientists.

The competition is sponsored by the National Research Council, the National Academy of Sciences, the National Academy of Engineering and NBS. NBS provides the financial support and the program is administered by the National Research Council.

Winners of the competition, their degrees, schools and division assignments at NBS include:

Robert S. Butler, computer science, Pennsylvania State University, Systems and Software Division.

Ilan Chabay, chemistry, University of Chicago, Analytical Chemistry Division.

Robert B. Feinberg, mathematics,

turn page

POSTDOCTORAL *continued*

University of Wisconsin, Applied Mathematics Division.

Ronald F. Fleming, nuclear engineering, University of Michigan, Nuclear Sciences Division.

Robert B. Green, chemistry, Ohio University, Analytical Chemistry Division.

Joseph W. Haus, Jr., physics, Catholic University, Heat Division.

Jan F. Herbst, physics, Cornell University, Optical Physics Division.

Warren W. Johnson, physics, Rutgers University, Cryogenics Division.

Neil D. Lerner, psychology, Brown University, Mechanics Division.

Rodney A. McKee, materials science, University of Texas, Metallurgy Division.

Eric B. Miller, biomedical engineering, Duke University, Electromagnetics Division.

Harry Morgan, physics, Howard University, Optical Physics Division.

John A. Mucha, chemistry, University of Pittsburgh, Quantum Electronics Division.

John M. Ondov, chemistry, University of Maryland, Analytical Chemistry Division.

George E. Parris, chemistry, Georgia Institute of Technology, Inorganic Chemistry Division.

Richard Pearson, Jr., chemistry, Harvard University, Optical Physics Division.

Bruce J. Pletka, metallurgy and materials science, Case Western Reserve University, Inorganic Materials Division.

David T. Read, physics, University of Illinois, Cryogenics Division.

William L. Rowan, physics, University of Texas, Optical Physics Division.

Peter J. Slater, mathematics, University of Iowa, Applied Mathematics Division.

Samuel R. Stein, physics, Stanford University, Time and Frequency Division.

John B. West, physics, University of California, Quantum Electronics Division. □

NBS Test Method Adopted as Tenative Standard by NFPA

AT its recent annual meeting in Miami Beach, Fla., the National Fire Protection Association adopted as a tentative standard a test method for determining smoke generation potential of materials. The test method was developed by the National Bureau of Standards.

Inhalation of smoke and toxic gases rather than burn injuries account for the majority of fire deaths. In addition, smoke can cause panic, damage furnishings and impede effective firefighting. One way to minimize this danger is to select materials with a low potential for smoke generation for use in critical areas (such as exitways and air conditioning ducts).

The Tentative Standards Test Method for Measuring Smoke Generated by Solid Materials (NFPA 258 T-1974) calls for testing with the NBS-developed smoke density chamber. The test method was first developed in 1966 at NBS as part of a technical study for the Department of Housing and Urban Development. There are now over 100 smoke density chambers in use throughout the United States.

In the test, specimens up to 25.4 mm (1 inch) in thickness are exposed to either flaming or non-flaming (smoldering) combustion. Smoke from the specimen accumulates within the 0.51 m^3 (18 cubic ft.) chamber and interrupts a light beam in the cabinet. The reduction of light transmission is used to measure the relative "quantity of smoke" the material may produce in a fire.

Dr. John W. Lyons, Director of the

Smoke density chambers such as this one are used to study smoke produced by burning materials.

Programmatic Center for Fire Research at NBS, says, "Acceptance of this test method as a standard is a key step in our efforts to devise rational ways to eliminate unreasonable fire risks from our midst. We need methods to measure other important aspects of the problem such as rate of heat release and toxic gases. But this method for visible smoke represents real progress."

"The Smoke Density Chamber Method for Evaluating the Potential Smoke Generation of Building Materials," NBS Technical Note 757, describes the test method. Copies may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Order prepaid ($0.45) by SD Catalog No. C13.46:757. Foreign remittances must be U.S. exchange and include an additional 25 percent of the publication price to cover mailing costs. Order microfiche copies prepaid by NTIS No. COM-73-50180 from National Technical Information Center, Springfield, Virginia 22151; the price is $1.45 (domestic) or $2.95 (foreign) a copy. □

New Data for Thermocouple Users Issued

A NEW set of the reference tables that will be widely used in industry and scientific laboratories for accurate calibration of thermocouples has been issued by the National Bureau of Standards. Thermocouples, with their simple construction of good accuracy (when properly calibrated), are especially convenient devices for measuring temperature.

Publication of the tables culminates a large-scale effort over several years by scientists at the NBS laboratories in Gaithersburg, Md., and Boulder, Colo., working in close cooperation with thermocouple wire manufacturers, instrument suppliers and the American Society for Testing and Materials (ASTM).

The new tables update and expand those published 19 years ago in NBS Circular 561 by Henry Shenker and others.

The primary motive in revising the tables was to take into account the changes in the International Practical Temperature Scale (IPTS-68). The new reference data are based on the IPTS-68 for temperatures above 20 K (−253 °C) and on the NBS helium-gas acoustical velocity scale from 4 to 20 K.

But even if the temperature scale had not been modified, as the authors point out, there are other good reasons why a new set of tables is needed. There have been significant changes in the chemical composition of some of the materials. A new platinum thermoelectric reference standard has been adopted.

Also, reference values for each material, in both positive and negative legs of the thermocouple, are needed for calibration and production control to insure interchangeability.

Greater precision in thermometry instrumentation has led to a need for smoother tables and also for values of the derivatives. And the now common use of computer-aided numerical analysis requires functional representations and approximations.

Information not usually found in data tables is given in special introductions to each thermocouple type. These discuss such topics as the history of development and early applications, typical chemical composition, temperature range, atmospheric restrictions, effect of impurities, handling techniques and precautions, standard limits of error and typical deviation plots.

Only the standard letter-designated thermocouples are described: noble metal Types S, R and B and base metal Types E, J, K and T. Their appropriate "single leg" (thermoelement versus Pt-67) values are also presented. The revised data reflect changes in the materials themselves and improvements in data fitting methods, as well as changes in the temperature scale.

The material preceding each set of tables includes the coefficients of the power series functional representation used in calculating the tabulated thermal voltages. Orders of the series representations range from two to fourteen.

With some exceptions, the main tables include the thermal voltage in microvolts, the Seebeck coefficient and the temperature derivative of the Seeback coefficient, all at temperature intervals of 1 °C. The temperature ranges vary for the different types, from a low of −270 °C for Type E to a high of 1820 °C for Type B.

Tables in the appendices represent the data with less precision, in millivolts and in degrees Fahrenheit as well as Celsius. Approximate second-, third- and fourth-degree polynomial expressions are given for each thermocouple in various temperature ranges.

Known as NBS Mongraph 125, Thermocouple Reference Tables Based on the IPTS-68, the new edition was prepared by Robert L. Powell, William J. Hall, Clyde H. Hyink, Jr., Larry L. Sparks, George W. Burns, Margaret G. Scroger and Harmond H. Plumb. It can be purchased (SD Cat. No. C13.44:125) for $4.55 from the U.S. Government Printing Office, Washington, D.C. 20402. □

Getting From Square 1 to Square 2

Take two unit squares and place them side by side so they form a rectangle two units wide and one unit high. Now choose a point A at random in the first square and, again at random, a point B in the second square. Then A and B will be a certain distance apart. Question: If we repeat the random choice of A and B many times, how far apart will they be on the average?

THIS question, not as easy as it looks, arises in transportation modelling and similar areas of operations analysis. Transportation models are used, for example, to find the most economical distribution network connecting factories and storage depots to local distribution centers in various parts of the country.

First suggested by Dr. Charles H. Johnson of the Applied Mathematics Division of the National Bureau of Standards, the problem of the squares was recently solved by Dr. Hans J. Oser, chief of the NBS Mathematical Analysis Section.

A plausible guess is that the average distance between A and B would be equal to the distance between the centers of the squares. That is, exactly 1. In fact, it turns out to be almost 9 percent larger. Oser's result, to five decimal places, is: 1.08814.

An approximate answer could have been obtained by the Monte Carlo method. This would employ a computer which, with the help of a table of random numbers, would actually carry out a large number of random selections of A and B, calculate their distances apart and then find the average of all the distances.

Oser, however, was able to solve the problem in a mathematically more satisfying and complete way by integrating explicitly the quadruple integral:

$$\int_0^1 \int_{-1}^0 \int_{-\frac{1}{2}}^{-\frac{1}{2}} \int_{-\frac{1}{2}}^{-\frac{1}{2}} \sqrt{(x_1-x_2)^2+(y_1-y_2)^2}\; dx_1 dx_2 dy_1 dy_2$$

The expression under the integral signs is the formula for the distance between two points based on the classical pythagorean theorem. The integration itself is a litle harder. If help is needed, details are given in Oser's article which will appear in a forthcoming issue of the *SIAM Review*, published by the Society for Industrial and Applied Mathematics. □

STANDARDIZATION *continued*

highway workers and to mark slow-moving vehicles.

As rapidly as they become available, these instruments are being put to use to provide support for the measurement system. They are being used to help instrument manufacturers ascertain that the instruments they produce can measure accurately. They are being used to provide standards directly from NBS and cooperatively through commercial standards laboratories. They are being used to investigate problems which are encountered in practical applications of the measurements. They are also being used to reconcile differences between national measurement systems. For example, NBS, in conjunction with the National Research Council Laboratories in Canada, is working to provide closer international agreement in measuring the fraction of light which is reflected diffusely from materials. Although this work is initially directed toward helping the paper industry in its international trade, these improvements will benefit a large number of other industries as well.

Colorimetric measurements, along with a large number of related measurements, are slated for an era of energetic expansion, and NBS is working to provide these measurements with a solid backing in standardization. □

CORRECTION

In the May issue of DIMENSIONS/NBS the Mount Sinai Hospital and School of Medicine in New York City was identified in a picture caption that related to a story on the accuracy of clinical laboratory tests. The picture was used as an illustration of a typical clinical laboratory setting. There was no intention to infer that tests in the Mount Sinai laboratory are inaccurate. DIMENSIONS/NBS regrets any misinterpretation that may have resulted.

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